BBN TECHNOLOGIES
A Verizon Company

EARS The Blue Team
BBN LIMSI UPitt UW

BBN+ Rich Transcription System for CTS

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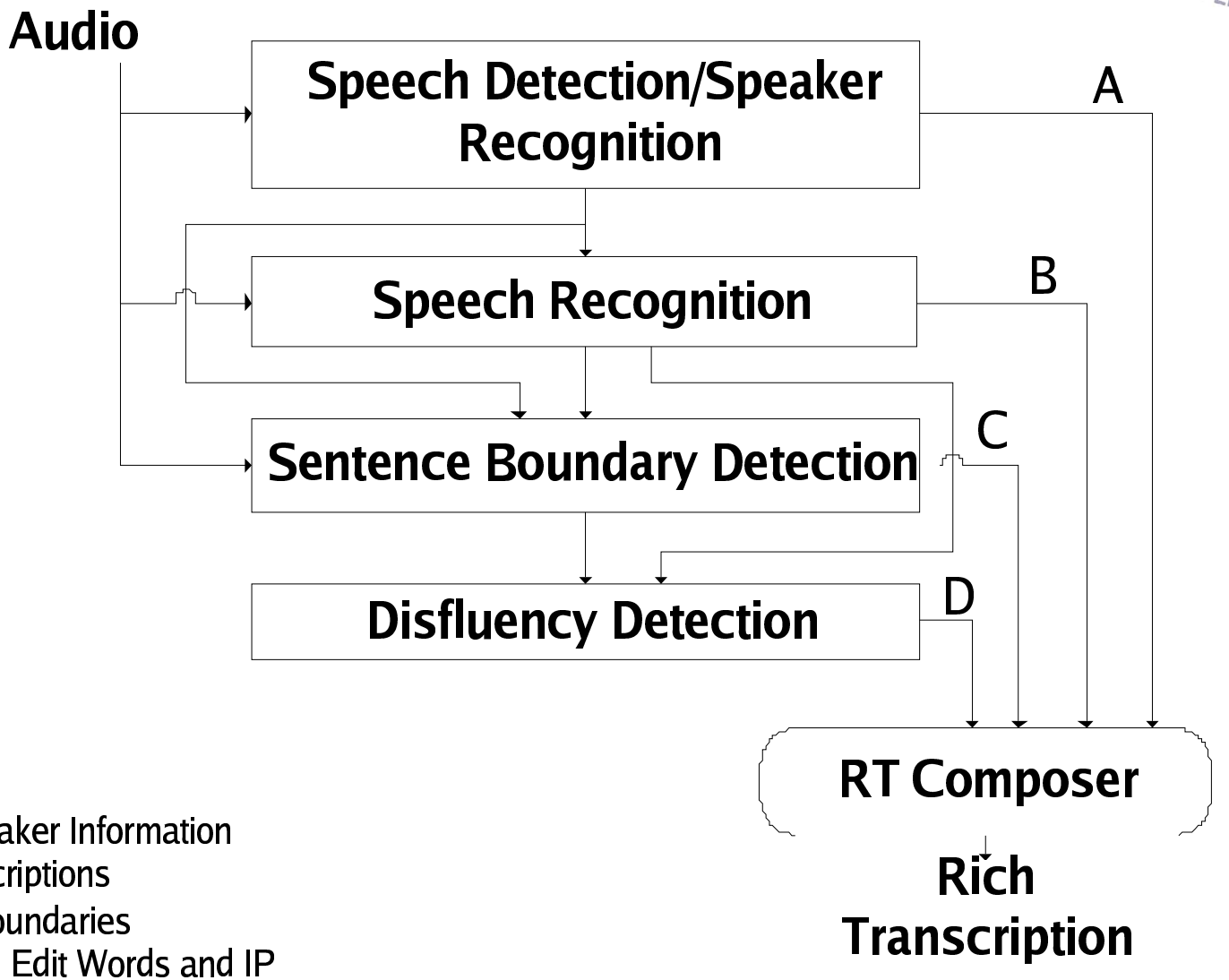
Outline

- **Rich Transcription System for CTS**
  - Overview
  - Speech Detection and Speech-to-Text
  - BBN Sentence Boundary Detection
  - SBD System Combination
  - Progress Results
- **Evaluation Results**
- **Post-Eval Progress on Sentence Boundary Detection**
- **Summary**

CTS Rich Transcription System Overview



A = Speech/Speaker Information
B = Word Transcriptions
C = Sentence Boundaries
D = Filler Words, Edit Words and IP

Speech Detection & Speech-to-Text

- **Acoustic Segmentation using Cross-Channel Event Modeling[1]**
  - **2 classes, *Non-Speech (N)*, and *Speech (S)*, for each channel**
  - **GMMs trained for each of the 4 Cross-Channel Events: *NN, NS, SN, SS***
  - **Viterbi Decoding to label each Data Frame with an Event**
  - **Silence or Non-Speech Segments are discarded**

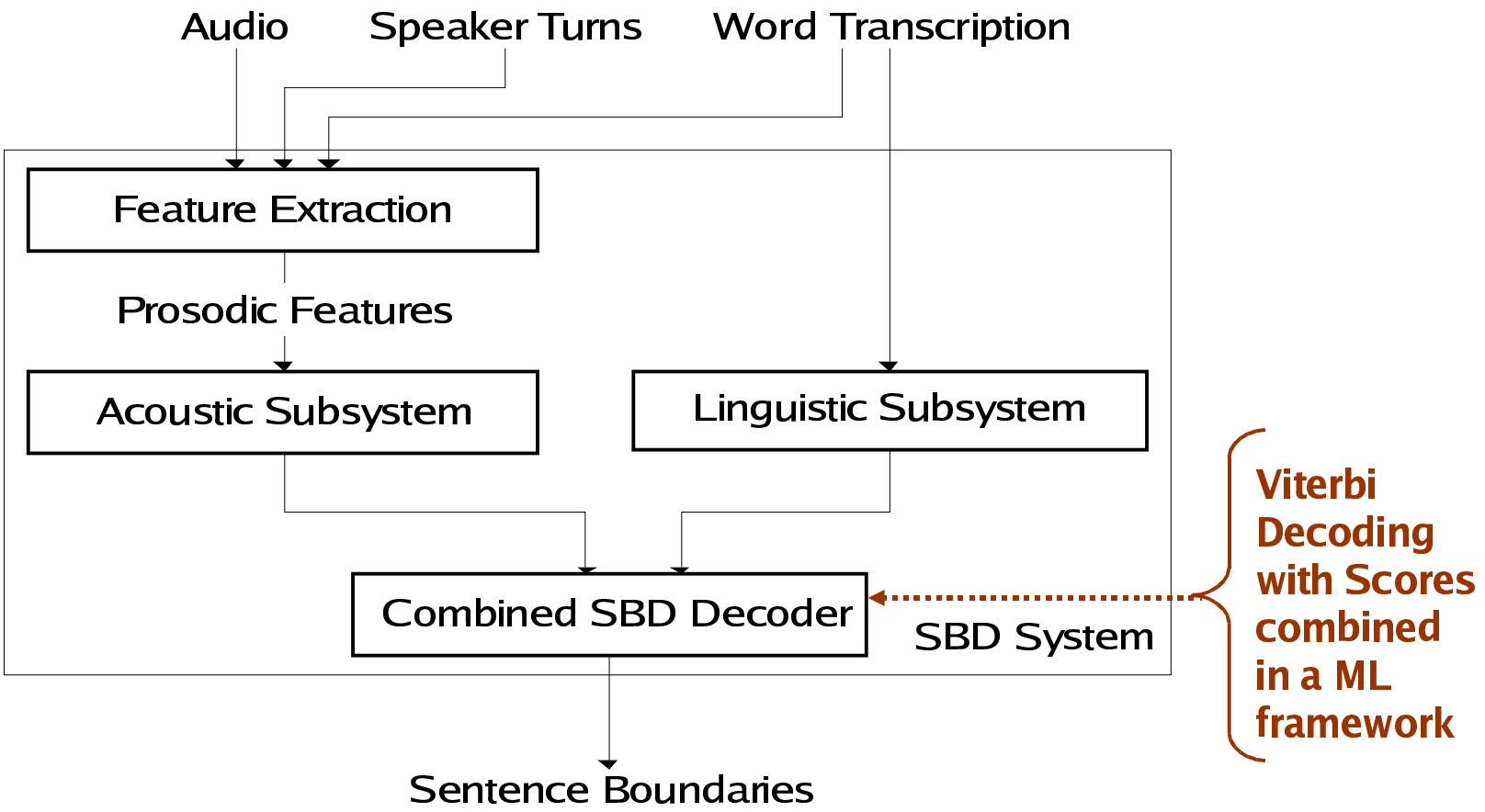
- **Single best BBN-only system used in RT03 Spring evaluation**
  - **Time constraint and prioritization**
  - **No pause-fillers in BBN + LIMSI combined STT output**

- **BBN + LIMSI Combined STT Primary Submission for RT03S was used for Metadata experiments post-RT03F Evaluation**

[1] Daben Liu, Francis Kubala, "A Cross-Channel Modeling Approach for Automatic Segmentation of Conversational Telephone Speech," ASRU'2003, to be presented, US Virgin Island, Dec 2003.

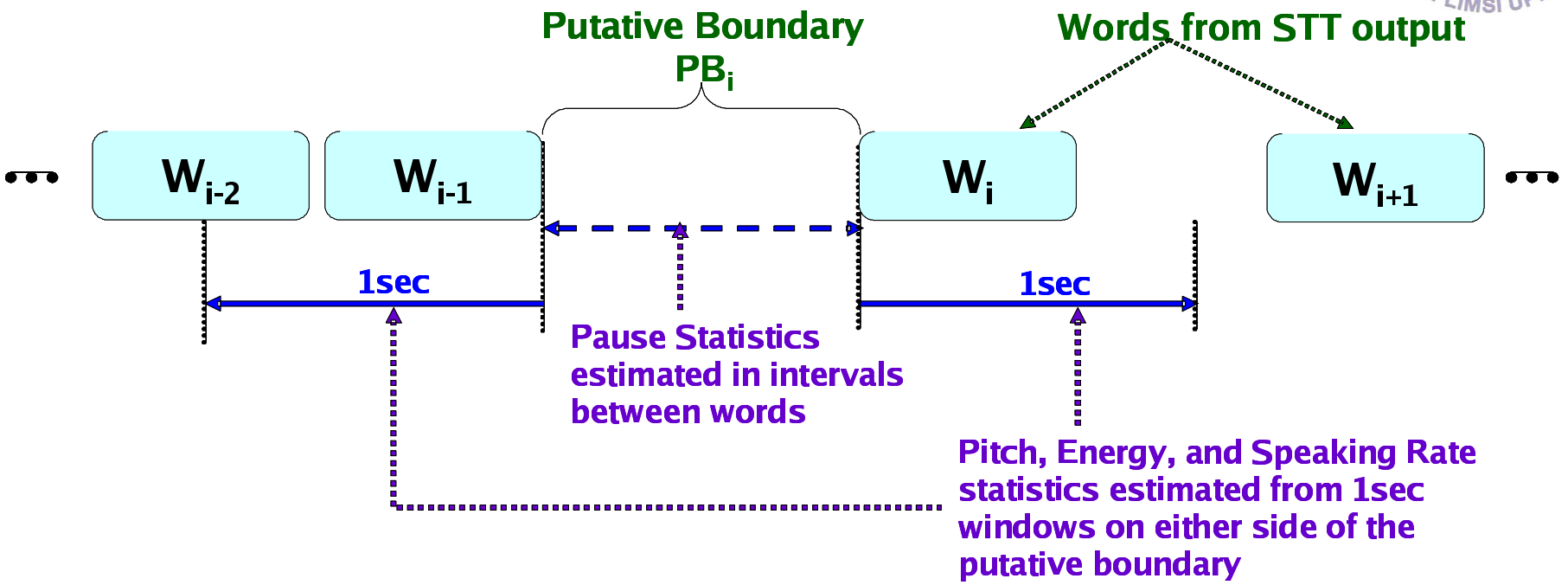
[2] R. Schwartz, et al., "Speech recognition in multiple languages and domains: The BBN/LIMSI EARS system," Proc. ICASSP-2004, Montreal, Canada, May 2004, appeared elsewhere on this proceeding.

BBN Sentence Boundary Detection System



- **Sentence boundaries hypothesized at each word boundary**

Prosodic Feature Extraction



Feature Type	Feature Description	# Features
Pause	• Pause Duration • Pause Attribute (Filler, Breath, etc.) • Time since last Pause • Normalized Pause Duration	10
Speaking Rate	• Absolute Value • Difference across Putative Boundary	2
Energy	• Absolute Values • Difference across Putative Boundary • First Difference of Energy	6
Pitch	• Discontinuous Chains in Voiced Regions • Interpolated Continuous Pitch • First-Order Pitch Differences	30
	Total	48

Acoustic Subsystem for SBD

- **Acoustic Subsystem**
  - 2-layer feed-forward neural network trained on 48 prosodic features
  - 3 Sentence classes: *statement*, *incomplete*, *no-sentence*
  - Features are discrete, continuous, and boolean
  - #Nodes: 48 input, 500 hidden, 3 output
  - BackProp training, minimum cross-entropy error criterion
  - 50 hours of LDC corpus used for training
  - NN scores are estimates of posterior probability of sentence class
    - Class likelihoods estimated by scaling with the class priors

Linguistic Subsystems for SBD

- **Word-based Linguistic Subsystem**
  - LM probabilities estimated by the BBN BYBLOS LM tools
  - Trigram LM with Sentence-class tokens inserted between words
  - LM trained on 500K words from the LDC 50 hour training trans.
  - LM scores used as transition probabilities in Combined Viterbi Decoder

- **Hybrid Word-POS Linguistic Subsystem**
  - Starts from same resources and tools as the Word-based system
  - Ratnaparkhi[3] MAXENT tagger used to hypothesize POS tags
  - Top 1000 frequent words left as is in the transcriptions
  - Rest of the words are replaced by their POS tags
  - Trigram LM estimated with Hybrid word-POS transformed transcripts

[3] A. Ratnaparkhi, "A Maximum Entropy Part-of-Speech Tagger," in Proc. of the Empirical Methods in Natural Language Processing Conference, 1996, pp. 133-141.

SBD Progress Summary for Dev03F

- **Word-based SBD System**

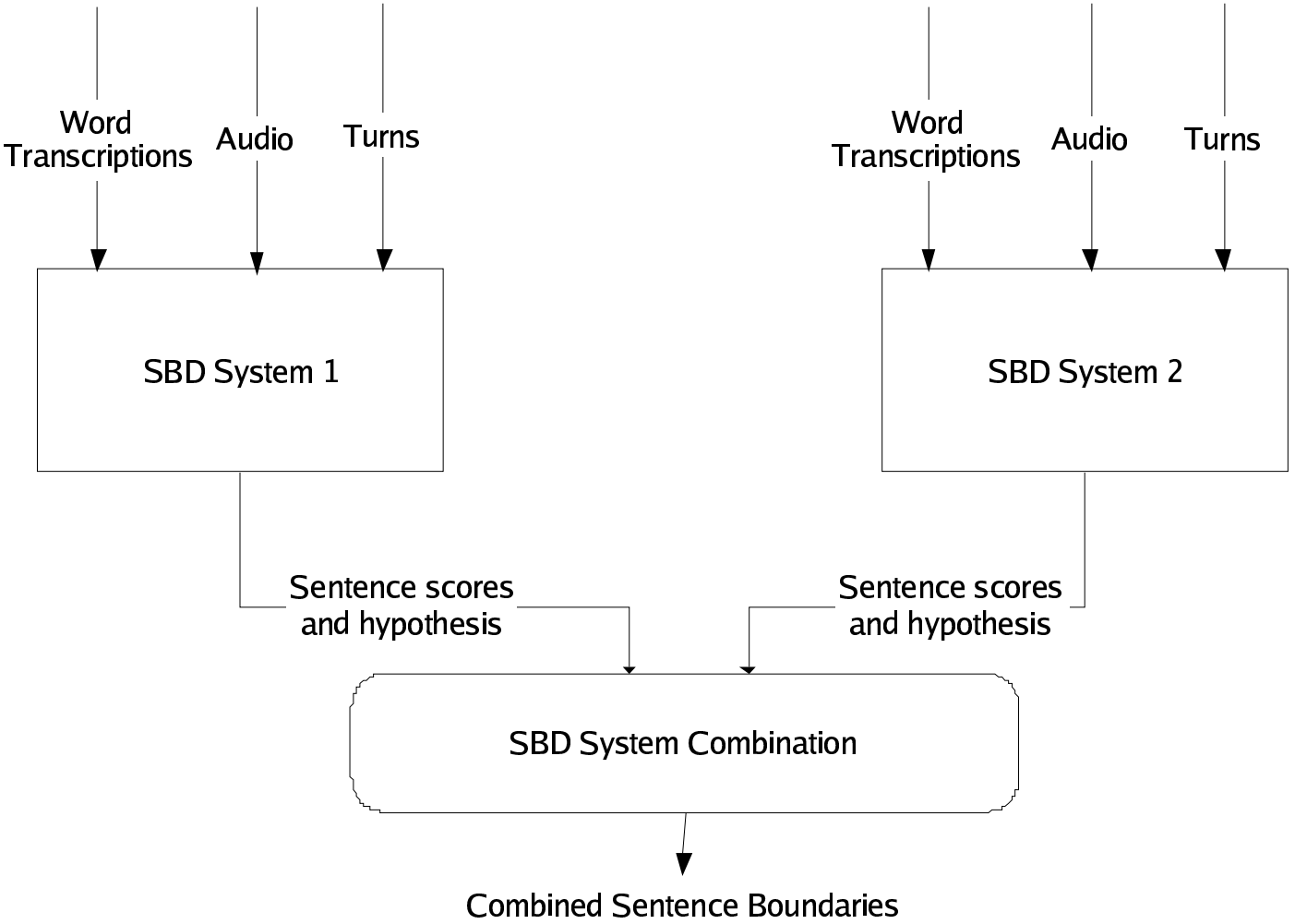
A.SBD Experiment	SER
August DryRun baseline (old training)	63.0
With compound words	60.8
Without compound words	52.5
100 frames feature window size	52.0
System tuning using class biasing	51.6

- **Hybrid Word-POS based SBD System***

SBD Experiment	SER
Pure POS LM	69.7
Hybrid Word-POS LM	52.3

* **Bug in the POS Training Procedure discovered post-evaluation**

SBD System Combination



SBD System Combination Overview

- **SBD System Combination with UW**
  - BBN Word-based SBD output combined with UW SBD output
    - Sentence class scores and SBD hypothesis at each word boundary used to create a 9 dimensional score vector
    - Sentence boundaries from reference transcriptions are transferred to word boundaries in STT hypothesis
    - NN with 50 hidden nodes trained using MSE backprop
  - During development, training and test are Jacknifed on 2 equal halves of the Dev03F set
    - For the Evaluation, SBD Combination NN is trained on the complete Dev03F set
- **System Combination of BBN SBD Systems**
  - Same Acoustic subsystem used with Word-based and Hybrid Word-POS based Linguistic Subsystems
  - Same NN-based procedure used for SBD system combination

SBD System Combination Results on Dev and Eval

- **BBN1 + UW**

SBD Experiment	Dev03F SER	Eval03F SER
UW Serial System	50.6	46.6
BBN Word-based SBD System	51.6	50.9
SBD Combination	49.0	46.7

- **BBN1 + BBN2**

SBD Experiment	Dev03F SER	Eval03F SER
Word-based system	51.6	50.9^{+}
Hybrid Word-POS based system	52.3	48.7*
SBD Combination	51.1	49.3^{x}

+ **Primary Submission**

* **Did not submit this system in the Evaluation due to non-positive results on Dev03F**

x **Contrast Submission**

Final Results

System	SBD	Edit	Filler	IP	SR	RT1	RT03
Dev03F							
BBN + UMD	51.6	85.4	49.5	70.5	11.4	27.2	37.3
Eval03F							
UW + BBN	46.7	88.5	51.0	68.4	10.1	25.2	33.9
BBN + UMD	50.9	87.9	48.8	69.0	10.2	25.3	34.7

- **Results were consistent going from Dev to Eval**
  - **Eval is an easier test set compared to Dev**
  - **Most of the gain in RT03 TER is due to better RT1 TER**

Post-Eval Experiments

- **Processed the BBN + LIMSI primary submission STT output for MDE experiments**
  - **Re-inserted pause-fillers from single-best BBN STT output into the Combined STT output**
- **Bug fixes in the Hybrid Word-POS based SBD system**

BBN SBD Improvements Post-Eval on Dev03F

- **Word-based SBD System**

SBD Experiment	RT1 TER	SBD SER
Pre-Eval System on Single-best STT	27.2	51.6
Pre-Eval System on BBN+LIMSI STT	24.3	47.2

- **Hybrid Word-POS based SBD System**

SBD Experiment	RT1 TER	SBD SER
Pre-Eval System on Single-best STT	27.2	52.3
Pre-Eval System on BBN+LIMSI STT	24.3	47.0
With POS bug fixes on new STT	24.3	46.3

Summary

- BBN combined with UW for Sentences
  - UW used the combined sentences to re-run TBL for Disfluencies
- BBN integrated with UMD for Disfluencies
  - Disfluency hypothesis from UMD integrated into a single RTXML file
- Despite insufficient time, BBN developed 2 systems for Sentence Boundary Detection in CTS
  - Hybrid Word-POS based SBD system (shows a lot of promise)
  - System combination (needs more work)
- Future Work
  - Combine output from BBN, UW, and UMD into an integrated RT output
  - Better SBD system combination techniques
  - Integrate Parsing for Rich Transcription